Art. VI.—*The Geology of the Portland Promontory, Western Victoria.*

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The area which I propose to describe is a promontory, terminating in three bold rocky headlands, Capes Bridgewater, Nelson, and Grant, and two open bays, and these features jointly constitute one of the most southerly extensions of Australia. The town of Portland, which gives its name to this promontory, is situated on the eastern side of its neck.

If we take a map of the locality, and run a line from Narrawong due west, until it cuts the beach at Discovery Bay, it will mark the base of the promontory, which we shall find to be about twenty-two miles across, while the length of its coast line is some sixty miles. The promontory is for the most part a low table land, which increases in height as we go from north to south, and which has bold bluffs for most of its sea margin. Where the coast is low, as it is between Whaler's Bluff and Narrawong, the strand crosses the site of a former shallow arm of the sea, the bed of which has been elevated just sufficiently to form dry land, and the old margin of this ancient bay is formed in part of bold bluffs, similar to those which edge so much of the promontory. The surface of this tableland is very undulating, which characteristic is, on the south-western edge, largely due to the presence of sand dunes, and elsewhere is the result of unequal erosion. Its highest points are Mount Richmond, 740 feet high, and the extinct Bridgewater volcano, 449 feet.

I.—Its External Relations.

From a geological point of view, the Portland Promontory is but a corner of a large area occupied by upraised seabeds of Tertiary age. Some time in the Eocene, if not before it, the south coast of Victoria and South Australia was depressed, and the ocean extended several great arms for considerable distances within the present shore line. One

of these gulfs stretched from near Adelaide to near Geelong, and occupied a great part of the valley of the Lower Murray. The Grampians and the Otway Ranges were islands in this tertiary sea. Miocene marine beds are exposed in the banks of the Murray at the north-west bend, and in the cliffs of the south coast, in patches from the head of the Australian Bight to Western Port, and a snow-white horizontal stratum of that formation is visible in the craters of some of the volcanoes which stud the centre of the region. These miocene beds rest unconformably upon mezozoic rocks at Cape Otway; upon paleozoic rocks in South Australia; and upon both of these formations at different points around the Grampians. They are nearly everywhere covered by beds of a more recent age, and at Portland, the miocene rock forms the base-course of the cliffs.

The area having been covered with marine deposits, was then raised sufficiently to expose them to view, and these, with others of æolian or volcanic origin, which are superimposed, will form the subjects of this sketch.

II.—The Portland Promontory.

In this locality the undermentioned formations are exposed, but I would remark, that no single section anywhere contains all the members:

Recent.—The sand dunes of the coast; the marine sands and clays of Narrawong Bay; the marine shell bed of Nelson; the latest lava flows of the Bridgewater volcano.

Pleistocene.—The false bedded or æolian limestone; the lower lava flows of Bridgewater.

Pliocene.—The lava flows of Nelson, and the lowest flows, with the bedded volcanic ash, of Bridgewater.

Upper Miocene or Upper Murravian.—The oyster bed of Whaler's Bluff; the lava flows of Portland Bay.

Lower Miocene or Lower Murravian.—The foraminiferous limestone, or chalk with flints, of Portland Bay.

III.—The Miocene Formations.

The foraminiferous limestone, or chalk with flints. This rock is a conspicuous feature in the cliffs at Portland. The

exposed portion forms a syncline about two miles long, the crest of which rises some thirty feet or so above the beach at the Whaler's Bluff, whilst the extremities dip out of sight at the lighthouse to the south, and at the Narrawong siding to the north.

The upper edge of the synclinal fold has a serrated appearance, probably due to the slipping down of masses of the much decomposed miocene basalt, which forms the upper portion of the cliff.

The rock is a snow-white material, moderately hard, but friable, and very porous. Its matrix is a chalky dust, a mass of microscopic foraminifera, which have been identified as being for the most part, globerigina bulloïdes, and orbulina universa. There is with these an abundant admixture of bryozoa, echini, pectens, terebratellæ, and pteropods, all more or less broken, and an occasional fishbone. The coarser ingredients are often arranged in layers one or two inches thick, and of considerable horizontal extent. These layers stand out in a slight relief on the cliff face, and this seems to be due to the presence in them of great numbers of siliceous organisms, which afford, by their partial decomposition, a siliceous cement, less affected by weathering than the calcareous cement which elsewhere binds the mass.

This chalk-like limestone is overlaid, conformably as it seems, by a bed composed principally of oyster shells (*Ostrea Sturtiana*). Owing to the talus of loose decomposed lava from overhead, it is not easy to say what may be the exact thickness of this bed, but I think that it probably averages a foot.

These two formations, the limestone and the oyster bed, weather more slowly than the volcanic rock above them, and consequently, the cliff face, where it is built up of these different materials, presents a section having a marked character. The portion composed of lava, slopes at an angle of about forty degrees, while that of limestone is almost vertical. (See Sketch H.)

These formations (the limestone and the oyster bed) are exposed at the surface only in one locality, that of the Borough of Portland. The outcrop there extends from the Courthouse, along the Cliff Road, to the bridge at the mouth of the Wattle Hill Creek, a distance of about a quarter of a mile, and thence it runs inland up the valley, for about a mile. The creek has cut through a great thickness of volcanic rock, and it has eroded to a small

extent the underlying chalk limestone ; thus the exposure of the latter at this spot is to be accounted for.

Although the chalk-limestone dips under foot at the Portland lighthouse, and is not again visible until the South Australian border is approached, yet there is evidence of its continuity. It must outcrop in the sea bed, not far beyond low water mark, and that frequently, for flints derived from it are plentiful on the beach as far as I went, viz., up to the east end of Discovery Bay. At Danger Point I found, thrown up on the lava rocks, a block of this chalk, about 20 lbs. in weight. The mass was clasped by the roots of a thick fucus *(macrocystis pyrifera).* Probably the seaweed had been violently torn up in some storm, and being very tough, it had wrenched the block of chalk, on which it had grown, out of its sea bed, and then had, by its great buoyancy, floated it ashore. Again at Bridgewater, there is a stratum of pure white colour, which forms a most conspicuous undulating stripe along the cliff face, for it is sandwiched in between ash-beds of a dark brown or buff colour. It is about five inches thick. It appeared to be the ejected powdery débris of a chalk substratum, that had been drilled through as the vent of the volcano was being formed. There can be little doubt but that the rock occurs there at a comparatively shallow depth.

Investigations by the Rev. Julian Woods and Professor Tait, into the fossils of these formations, and of their extensions along the coast and elsewhere, place the oyster beds in Upper, and the foraminiferous limestone in the Lower the Murravian series—respectively the equivalents of the Upper and Lower Miocene.

IV.—The Volcanic Rocks.

Rocks of volcanic origin cover a large portion of the Promontory. The most considerable accumulation occurs along the south-west shore of Portland Bay. It extends from Cape Grant to the Narrawong siding; thence it turns to the north-west, or inland ; its thinned edge crosses the railway line near the nine mile post ; it overlaps Bat's ridges on the north side of them ; and then it dips under the falsebedded limestone at the Black Gully on the Bridgewater road. Probably there are outliers of this much eroded rock outside of this area, just as there are small patches of the underlying limestone exposed within it.

The Rev. Julian Woods thought that this lava flowed from a crater situated where isolated rocks now form the group known as the Laurence Rocks. I know of no facts inimical to this theory, and the circumstance that the lava beds thin out as they recede from that neighbourhood is in its favour. I searched carefully for elongated vesicles in the lava, as evidence of the direction of its flow, but could find none *in situ*, though I saw them in many of the loose boulders, where they were valueless to me. It is right to say, that Mr. Dennant, F.G.S., questions this view, on the ground that the Laurence Rocks are capped with limestone and not with ash, as asserted by Mr. Woods. As I did not visit the islets, I cannot say which of these authorities gives the correct facts, but it seems to me that such a low vent might easily have become covered up with a limestone deposit subsequently, and, therefore, I think that Mr. Woods may be right in his theory as to the location of the crater, even if he should prove to have been wrong as to the nature of the capping.

The lava of this area is in some places at least 150 feet in depth, but the mass is built up of an enormous number of separate flows. These vary in thickness from one to ten feet. The beds are lenticular in transverse section, and none that I saw were more than 100 yards wide. They are bedded more or less horizontally. The thickness of the whole mass varies greatly within short distances, and I think that much of this inequality is due to aqueous erosion, for the most marked differences occur in the neighbourhood of the existing or of the sites of former watercourses. The biggest of these have but a feeble flow now, though it is likely that during some portion of the post-miocene period their streams were of a much greater volume than they are to-day, and consequently, that they then had much more power. This eroding action has been further promoted by the fact that the coast edge has been rising rather faster than the parts inland; for just as a circular saw cannot cut into a log unless the latter be pushed against it, so a stream, that has reached its base-level of erosion, cannot deepen its channel, unless the latter is being raised so as constantly to expose a lower stratum of of its floor to the scour. The south-east margin of this peninsula has cockled up, but the flowing water has preserved its channel by cleaving the rim to sea level.

In places the lava lies immediately upon the miocene shell bed, but I did not detect any changes in the latter, such as are usually caused by contact with heated masses.

I was much struck with the great differences in colour, degree of hardness, vesicularity, decomposition, and thickness of bedding, displayed by the lava within short distances.

Woods has tested the rock, and he assigns to it the following composition :—

$Si. O_2$	...	...	...	·60
$Fe. O.$	...	...	...	·20
Al_2O_3	...	...	...	·10
$Ca. O.$ $Mg. O.$ $H_2O.$	...	...	...	·10
				1·00

He terms it an augitic or doleritic lava, and it seems to me that it might equally well be called an andesite.

A fine grained yellow, slightly vesicular and very decomposed lava occurs in a little bay immediately south of the lighthouse. It is found at, and a little above, the low water level, and its softness probably accounts for the formation of the little bay. Similar flows occur at the sea level in all the indentations between this bay and Danger Point, and I noticed that wherever the coast juts out the rock at the sea level is a dark durable lava. The yellow lava appeared to me to be of a more acid nature than the darker kinds, for it preserves its light colour even where it is very hard and undecomposed. At Black Nose Point the rock is a dark massive hard basalt, and it is so very vesicular that a gas cavity, which I measured, had a major axis 18 inches long and a minor one measuring 12 inches; and I saw many others as large as it. A tiny rivulet enters the sea near to this point, and thereabouts the cliffs lose their height, and then the coast forms a low double shelf. (See Sketch K.) A pebble ridge extends from this place to Danger Point, a distance of one mile. The boulders are of basalt, with an abundant admixture of rolled blocks of volcanic ash, and flints. The ash may come from the Laurence Rocks, one mile to seaward of the ridge; but if it does not, it is hard to say whence it is derived, as there is no other deposit of the material, known to me, nearer to it than Cape Bridgewater, which must be 15 miles distant. This volcanic formation

dips out of sight under pleistocene limestone about two miles to the west of Cape Grant.

Another volcanic flow occurs at Cape Nelson. The traveller from Portland strikes the south end of Nelson Bay, at a point about two miles from the lighthouse. He there finds himself standing on the brink of an amphitheatre of limestone cliffs, almost vertical, and in height from 150 to 200 feet.

The beach which fringes the centre of the bay disappears towards its two seaward extremities, and here the lofty cliffs are undercut by the waves. Hereabouts also, there is a slight bend in the line of cliff, low down on the salient angle, of which a bed of black lava is a conspicuous feature in the buff coloured wall. It is about three or four feet thick; it appears to be about thirty feet above the sea level, and it dips inland, *i.e.*, to the south-west, at an angle of about six degrees. The same bed re-appears in the next jutting point, which is distant about 300 yards to the south. A second flow appears below it, some twenty feet thick of limestone lying between the two beds. The bottom flow forms the base of the cliff. Here again, the dip of the flow is inland (south-west), but the angle is about ten degrees. (See sketch T.)

As the cliffs were inaccessible, I had to make my observations from above, at a distance of about 250 yards.

The lava again creeps up the cliff from under foot as we proceed south, and it forms its base, from this point outwards, all round the cape. I was able to descend and examine it only at one point, and that was under the lighthouse. The cliff there is 180 feet high. The upper 100 feet consists of a current bedded calcareous sandstone (termed by me limestone, for brevity), and the lower 80 feet of black lava, the latter formation apparently subdividing again into two major divisions, each about 40 feet thick, and each made up of several flows. The lava forms two platforms, and the cliff has a profile shown in the sketch. (See sketch M.)

The under surface of the limestone is as level as a shelf, and in some places, it projects over the lava as much as 20 and 25 feet. (See sketch J.) The latter weathers the faster of the two rocks, and its face is tattooed with the concentric rings of brown and yellow, characteristic of the decay of lava. From the centres of many of these boulders nodules of darker rock project, and a great number of

greenish-white zeolites stud the surface of the lava, standing out in bold relief. Streams of hard water leak out at the junction of the two formations. These have coated much of the lava with a crust of slippery magnesian travertine. Its colour varies between shades of dirty brown and dirty green, but these tints may be due to the growth of microscopic plants on the moistened surfaces. Every pool in the upper rocks has a margin of lime crystals, due to the evaporation of this hard water. As the water drips from the limestone cornice it forms stalactites, the white forms of which, being relieved by the shadow cast behind them by the deep ledge, stand out as a rude dog-tooth moulding along the junction. (See sketch V.) The step-like profile of the cliff indicates a change in the sea level. Volcanic rock appears to underlie the whole of this cape. It dips under limestone in Bridgewater as in Nelson Bay, but what its northerly extension under the limestone may be, it is impossible to say.

The third occurrence of volcanic rocks within this area is at Cape Bridgewater. The dunes end, and bold hills begin, at the west end of Bridgewater Bay, half way between Vance's and McKinlay's. At the point where the fishermen's undercliff road starts, smooth wave-worn tabular rocks peep up through the sand of a wide beach, between the high and low water marks. These are stratified ash beds of a buff colour, but they are speckled with minute black cinders. The layers are each from one to four inches thick, and the tint of each is proportioned to the abundance of the cinders. On the beach one hundred yards south of these ash beds other smoothed rocks crop up, but they are composed of a dark hard lava. Immediately beyond these rocks, beds of both ash and lava are to be seen in the face of the cliff. The ash here is intensely hard, and is very massively bedded. The colour of the upper part is buff, and that of the lower is brown, and the upper edge of the brown bed forms a syncline. The dip of the beds varies both in angle and direction within short distances. The angle of those first seen does not exceed ten degrees, and their dip is north-east; but near McKinlay's (half a mile further south) the dip is first east, then east south-east, while their angle has risen to 40°. The ash begins to contain larger scoria as we go south, and these have their vesicles filled with amygdules. The upper edge of the ash is some 25 feet above the beach, and the upper part of the bold cliff is composed of the false-bedded limestone, first noticed at Cape Nelson.

At the fishermen's huts, the limestone rests directly on the lava, but it is unaltered along the plane of contact.

About a quarter of a mile south of the fishermen's huts the cliff shows an interesting section. At the top there is about 40 feet of limestone, then 30 feet of thick bedded lava, 3 feet of olive green ash, in thin layers, then eight or nine distinct shallow flows of black slaggy lava; and under these 5 or 6 feet of olive green bedded ash, and then the face is marked by a bouldery beach. The special feature of the section is the lower lava flow. The nine thin beds of the latter form a mass crescentic in section, with the horns pointing slightly downwards. It is about 20 feet thick in the centre, and at a distance of 50 feet on either side of the central point it tapers out. No parting material separates the several flows; the lowest lies conformably upon an ash bed, and is tolerably compact, but the top one has a slaggy scoriaceous surface. The south edge of the flow is truncated, by the cliff turning sharply to the west, so as to give a section of it almost at a right angle to that just described. In this longitudinal section the lava and ash beds are seen to have a dip to the east of forty degrees. (See sketches X^1 and X^2.)

About 50 yards south of the crescentic-sectioned lava beds, the ash beds are traversed by a vertical lava dyke, which, emerging from the sea, rises to a height of about fifty feet. It is composed of two slabs of about equal size, the total thickness of the dyke being about two feet; its strike is north-east and south-west. The ash beds are darker for a few inches on either side of it, as if they were somewhat burnt.

Mr. Dennant has recently stated, that this dyke joins the overlying basalt, and his paper contains a drawing showing such a junction. After a very careful examination of the cliff, I must say that I could see no such confluence. The dyke tapers to a point at the top, and terminates in the ash at a considerable distance beneath the lava. There may be a junction, nevertheless, though it is not visible in the section. To the south of the dyke most of the cliffs rose sheer out of deep water, and could not be reached. Examined through a glass, they presented a solid smooth wall of ash 250 feet high, and nearly vertical. It will be noticed, that between the first place of appearance of the ash and this point, a distance of half a mile, the ash beds have increased in thickness from 5 feet to 250 feet, and their dip has increased from ten to forty degrees. The cinders contained in the ash have

increased from the size of peas up to that of blocks a foot long. At some points I noticed pseudo-dykes in the ash, formed of a sort of soapstone.

Having ascended the cliffs from the fishermen's huts, I found that the limestone disappeared about half way up the hill, at about 200 feet above sea level, and lava, weathered into boulders, then showed through the turf. When nearly over the dyke, I found that the hill rose inland from the cliff edge very steeply. Its crest is a few hundred feet distant from the cliff edge, and it has an altitude of 449 feet. Over an area of six or seven acres the surface is a mass of rugged lava. Immediately to the north of this outcrop is a a slight hollow or dell, in extent about one acre. This depression may be the nearly obliterated vent of a small and much decayed volcanic cone. A lava flow extends from the rocky crest towards the south-west; it is about a chain wide and a quarter of a mile long, and it does not reach the sea. This flow has a quite fresh look, and it is the only one within this area that I have seen, which has such a very recent appearance. Both the strike of the lava dyke and the dip of the lenticular lava bed are directed towards this crater. The dip of the ash beds from a point near Vance's up to Cape Bridgewater forms a series of radial lines, which centre here also, and if the strikes of the several beds were worked out, I believe that they would form segments of circles grouped around this hill.

About a mile south from the crest of this extinct volcano, the cliffs, from trending south-east, turn abruptly to the west. This corner forms Cape Bridgewater. Directly the cape is rounded the ash beds dip steeply to the north-east, and disappear under level bedded lava flows, which then form the whole height of the cliff. A mile to the west this cliff is 150 feet high perpendicular, and built up of level layers of solid lava, as regular in their courses as mason work. A thin stratum of the false-bedded limestone and some loose sand cap the whole. (See sketch P.)

At Liddle's Watering Place, a spot some three miles north-west of the crater, the cliffs are 130 feet high; the lava portion being about 70 feet, and the limestone 60 feet thick. The lava is hard and dark, and occurs in rude hexagonal columns. It has been cut into two well-marked wide platforms, and the upper one is greatly encrusted with travertine, deposited by the calcareous springs. (See sketch R.)

It will be noticed that the height of the lava in the cliffs just west of Cape Bridgewater is 150 feet. At Liddle's it is only 70 feet, and at White's, only a mile away, it disappears altogether under the limestone, which, appearing at the Cape as a layer a foot or so through, becomes 60 feet thick at Liddle's, and is still deeper at White's. Therefore it appears to me, that this cinder cone was breached on its south-west side, at the extreme point of Cape Bridgewater, where the wall of ash ends abruptly, leaving a chasm which was then filled to its brim with lava flows.

I set down the ages of these volcanic rocks as being pliocene, pleistocene, and recent. At Portland the extremely decomposed and oldest flows lie conformably upon the Upper Miocene oyster beds. At Nelson Bay a lava bed is intercalated between beds of limestone of pleistocene age, and at the Bridgewater crater a great thickness of rock is crowned by a little lava flow, already described, which looks as fresh as if it had welled out but a few years ago, although the lower flows dip under the pleistocene limestone.

V.—The Pleistocene, or False-bedded Eolian Limestone.

This is the most extensive formation exposed in this district, and its position upon the western or windward side of the promontory, challenges attention when we are considering its mode of origin. The rock is a moderately compact breccia, composed of broken marine organisms, mainly shells, cemented together by a calcareous paste, which is coloured by iron oxides. These latter give to the strata various shades of red, yellow, and grey. The stone appears to harden with exposure, and this probably is the result of the more complete solidification of the external portions, by the infilling of all the interstices of that part of the breccia, with travertine, supplied by the soakage through it of rain and spray, carrying carbonic acid.

The composition of the rock seems to vary slightly from point to point, for Mr. Woods describes it as containing lime, magnesia, and silica, with traces of sesqui-oxide of iron, and sulphate of lime, while Mr. Dennant says that it is a carbonate of lime, with four per cent. of silica.

The formation is composed of beds from 10 to 20 feet thick, and these are disposed horizontally. They are all

markedly false or current bedded, the minor laminations being about two inches thick, and seldom longer than 15 or 20 feet. The latter dip in all directions, and at all angles up to about thirty degrees. Mr. Dennant asserts that their dip is often *quâ-quâ-versal*, though I cannot confirm this statement. I understand, that a dip to be *quâ-quâ-versal*, must slope from a centre, but I have discovered none that were so arranged; still, if the term may be stretched to describe strata which, being contiguous, dip in all directions, but which nevertheless, have no relation to any common centre, then I can admit that it is applicable in this case.

Another statement made by Mr. Dennant is, that the laminations of the strata are "always parallel to the bedding planes." My observations failed to discover any example of this parallelism. The laminations were at an oblique angle to the bedding planes in all the sections that I saw, and I noticed that nearly every stratum was characterised by a mean angle of dip peculiar to itself, and that this mean angle was persistent in the same stratum, over long distances. The section at Liddle's Watering Place is an interesting example of this peculiarity. (See Sketch R.)

The formation is very barren of fossils, but Professor Tate has discovered in the South Australian extension of the deposit, land shells at various depths. Upon the evidence afforded by these land shells, the rock has been pronounced to be of an eolian origin. Mr. Dennant believes that it is a mass of consolidated sand dunes, and states that the outline and structure of the original dunes are displayed in some of the cliffs, but I have not been able to recognise them, even in the "Cloven Rock," the locality which he instances. The stratification of the rock, as illustrated by the Liddle's Watering Place section, is I think, incompatible with the view that the formation consists of sand dunes merely consolidated, for there, each stratum has its own horizontally arranged peculiarities of colour and lamination, a feature which is not illustrated in the sections of any sand dunes that I have seen, and which could not be produced, as far as I know, where the materials accumulate upon the undulating surfaces assumed by blown sand.

It may be said that the horizontal bedding planes are merely divisional joints, due to changes in the materials occurring subsequent to their deposit. Were such their origin then, the false bedding would, as often as not, pass

out of one stratum into the next, and the colouring matter would be distributed without reference to the lines of joint. Now, I have already said that each pair of bedding planes enframes its own pattern of dip, and that it outlines a particular tint. Such a linear distribution of these features must indicate a different age, and a separate, though otherwise similar origin for each stratum in the formation, and if this deduction be allowed, then it must also be admitted that the rock cannot be merely consolidated sand dune.

The embedded land shells would appear to indicate that its origin must be eolian, but it seems to be equally clear, that the several strata must have been, *ab origine*, so many distinct formations deposited at different times, and under conditions which, although mainly similar, were variable in some minor respects. It seems to me that each of these rock courses is but the truncated remnant of a separate generation of sand dunes, a thin horizontal slice of their confluent hardened bases. What agency is there that could grind down such mammillated deposits, until but a a thin veneer of the material of each one is left? The only one known to me is that of the sea, assisted by repeated slight land oscillations. Rapid and repeated changes in the sea level are not improbable occurrences upon a coast line which is studded with volcanic craters, and scarred with raised beaches. The latter phenomena testify to a condition of unstable equilibrium existing between the subterranean forces, which would account for the mobility of its surface, and would explain its alternate emergence and immersion; its burial under a beach drift at one period, and its disappearance under a shallow sea at another.

This limestone deposit does not appear to be a thick one, for many years ago, two bores were put through it in a search after coal in Nelson Bay. The records of the strata passed through appear to have been lost, but Mr. Must, who with the Messrs. Henty, controlled the enterprise, tells me that the first bore was sunk on the top of the limestone cliff, and that it was stopped by basalt. The second one was started on a ledge which occurs low down in the face of the cliff. The rod passed through the limestone into a thin stratum of red sandstone, and then through beds of red and blue clay. It was stopped in the latter at a total depth of only seventy feet. This would give 250 feet as the thickness of the limestone at this point, and this is probably as thick as it is anywhere. No basalt

was met with in the second bore, and no chalk, although it is likely that the latter would have been reached within a short distance further down, as elsewhere, a shallow deposit of red and blue clays overlies it.*

For instance, a Mr. Smith has sunk to obtain water in his strawberry garden, near to the Bridgewater Road, and within the Borough of Portland. He tells me that after passing through beds of red and blue clay, and then through a shell bed, the bore entered the chalk, and struck water at a depth of thirty feet. At this spot there is no eolian limestone, and the surface stratum is a very thin deposit of decomposed lava.

The centre of the Portland Promontory is occupied by a low range of hills, known as Bat's Ridges. These hills are an extension of this limestone formation, and they are perforated by many caves, some of which are of considerable length. Professor Tate has assigned this limestone formation to the pleistocene period, and while the Rev. Julian Woods says that it is pliocene, Mr. Dennant describes it as "Recent."

VI.—The Recent Formations—the Sand Dunes.

Sand dunes occur in long narrow strips, bordering those portions of the coast which are exposed to the strong south westerly winds which prevail here.

Their spread inland appears to me to be an exceedingly recent movement, due to artificial causes. Mr. Kennedy who has resided at Bridgewater for forty years, tells me that when first he came to the district, the sand dunes were very much narrower than they are now, and that their surfaces were then bound down by various grasses. These began to be eaten down when cattle were introduced, and the coastwise traffic commencing simultaneously, the dray wheels destroyed the roots left by the cattle, and so let loose the sand. By these means the surface features of the parts adjacent to the coast have been greatly altered of late years.

The dunes are composed of comminuted shells, mixed with a little siliceous sand. The materials are coarser than those which compose the false-bedded limestone, and they

* Had these operations been conducted under the direction of any one with geological knowledge, the bore would have been started in the neighbourhood of the Botanical Gardens, at Portland, in the chalk. The money was wasted in putting a bore through the limestone at Nelson Bay.

are considerably coarser than the sand now on the beach at the spots where I took samples for comparison, but Mr. Dennant tells me that he has found beach sand in the locality of a very similar character.

Where the dunes have been breached I saw some very faint traces of bedding, the layers being about two inches thick. I saw no horizontal divisions, and no linear arrangement of either dip or colour, such as characterises the false-bedded limestone. On the contrary, all the material seemed to be perfectly homogeneous and almost structureless at every level that I could examine it.

VII.—Marine Beds, Bridgewater.

On the summit of the Cape Nelson cliffs, 180 feet above sea level, the limestone is partly covered by a sand bed, which originally may have been three or four feet thick, but which is now so far blown away that only wind-swept and smoothed knolls are left. All these knolls are capped by a bed of recent shells, two or three inches thick.

A similar shell bed occurs further inland, as for instance where the Bridgewater road crosses a little rivulet opposite to Wilson's farm. This spot must be two miles from the beach and about 175 feet above sea level. The vehicular traffic has cut trenches into the soil and these expose shallow sections. These show a stratum of shells a few inches below the surface. The shell bed rests upon a shallow sand bed, and this lies upon the pleistocene limestone. As the road winds round and over the hills, this bed is noticed closely following their contours, indicating that they are parts of the bed of a sea or lake which has disappeared.

I noticed upon the crests and sides of many of the hills, patches of a much whiter and denser limestone. These may be deposits of travertine, due to the oozing out of drainage waters, which have now, from some cause, ceased to flow; but I understand Mr. Woods to say, that they are marine deposits, formed when these rocks were the bed of a shallow sea, and that he has found marine fossils in them. These marine deposits have suggested to me that, at the time when the land stood 200 feet lower than it does now, and when these hills were just immersed, that then high lava cliffs probably extended as a sea wall or breakwater for some miles to the south of the present coast line.

That these cliffs were somewhere breached so as to admit the sea over the lower land behind them, and thus an inland sea was created, resembling, in the form of its sea wall, Port Phillip Bay, Port Jackson, or the Gippsland Lakes. In the quiet waters of such a closed-in sea, the undulating surfaces of the limestone hills, with their shelly investiture, might have been preserved intact. Similar shaped banks now occur in Port Phillip Bay, especially towards the Heads, and they are known to be similarly covered with shells. The slowly retreating waters of Port Phillip Bay are to-day leaving behind them, all round its shores, shell beds in nowise different in appearance from those on the hills and cliffs of Nelson and Bridgewater. These shell beds are intermediate in age between the pleistocene limestone and the recent dunes.

VIII.—Marine Beds, Bolwarra.

Between Portland and Narrawong the cliffs recede inland. Alluvial flats, crossed by low sand ridges, take the place of the bold hills of lava and limestone. A very old resident of Portland, Mr. Douglass, to whom I am considerably indebted for local information, tells me that a farmer living on these flats has bored for water. The rod passed through many beds of drift sand, mud, and clay, and reached a depth of 100 feet without meeting with any indication of a bed-rock. From the nature of these beds, I judge that the locality was once the site of an arm of the sea, and the present contour of the land suggests that, in the immediate past, a narrow strait cut off the bold extremity of the Portland promontory from the main land, leaving it a small, steep-sided, volcanic island.

IX.—The Raised Beaches and the Sea Caves.

All along this coast there is evidence of much recent change in the sea level. On the Portland beach, in front of the Court House, the chalk cliffs are undercut, showing that the waves once reached them. The entire cliff face is vertical, and is so sharply cut and so slightly weathered, that much time cannot have elapsed since this happened; but the grass-grown sand heaps at their bases indicate that the sea has retreated.

Nearly opposite to the south end of this cliff, a boulder bed bars the creek mouth, the boulders of which have probably accumulated in comparatively deep water. Now, however, it forms a grass-grown ridge, about 6 feet high, and permanently out of the water, so that houses have been built upon it. The sea is now removing this spit by cutting it backwards.

Mr. Pile, a shipping agent long resident at Portland, assures me that a shallowing movement has been continuous, rapid, and marked along the south coast for many years past.

The local fishermen say that many well-known rocks, to reach which they had to wade through the surf thirty years ago, are now high and dry ; and the masters of the coasting steamers declare that, from the Otway westward, the soundings are getting shoaler. And there is other evidence which shows that an upward movement of the land, or the retreat of the ocean, has a considerable antiquity. For instance, in the sloping face of the cliff, underneath the Portland lighthouse, I found a bed of recent shells 2 feet thick (sandwiched between beds of decomposed basalt, which are evidently only so much talus), and situated about 30 feet above sea level. (See sketch I.)

Between Blacknose and Danger Points, there is a raised beach, about one chain wide, and this also is about 30 feet above sea level. It is covered with a growth of large ti-tree and shrubs. (See sketch K.)

In Nelson Bay, the limestone cliffs are from 150 to 200 feet high, and nearly perpendicular. At a considerable height above the beach, there is a shelf which runs for miles. It is quite a chain wide in many parts and it is well covered with trees and shrubs. (See Sketch L.)

At Cape Nelson there are two well defined platforms cut out of the basalt, one at about 10 feet, and the other at about 30 feet above sea level. (See Sketch M.)

As Bridgewater is approached by the road, the country is ridged and furrowed with rolling hills, mostly parallel with the beach. Half a mile east of Vance's the road enters a trough formed by two of these land rolls. The seaward ridge seems to be merely a sand dune, but the inland one, presents to the road a vertical wall of limestone, undercu into caves. I estimate that the base of this cliff must be quite 20 feet above sea level, and be seven chains distant from high-water mark. This is an old sea cliff, and its

appearance is best shewn in the sketch and section. (See Sketches S^1 and S^2.)

At Cape Bridgewater a wide flat platform occurs in the hard ash beds some three or four feet above low water level; it has once been quite a mile long, but it has been greatly broken down. It is now 50 feet wide in places, and it is level in a striking degree. (See Sketch O.)

At Liddle's watering place there are two ledges in the basalt, one about five feet, and another at about 25 feet above sea level. (See Sketch R.)

All these platforms are now disappearing. The action of the sea at its present level is highly destructive of the lower ones, and in the very act of breaking them down it is carving out a still lower shelf some 15 or 20 feet below those which are being destroyed.

In consequence of this action, the ledges everywhere are more or less breached; in many places they have been almost entirely removed, and the remnant form ragged edged, but broad flanges along the cliff foot.

Another evidence of the altered levels is supplied by the caves at Bridgewater. They occur only in the cliffs which are composed of volcanic ash. The largest one is situated at the extreme point of this Cape, which it drills through. My examination of it was hurried by the nature of the weather, so that I had not time to measure its dimensions, but I should say, that it is about 300 feet long, 60 feet wide, and 40 feet high. At low water the floor of the south or ocean end is three feet above the tide, and that of the north or Bridgewater Bay end, has then about four feet of water over its sill. The sea flows into the cave for a distance of about 70 feet in ordinary weather, and the waves break upon a steeply inclined beach of sand and shingle.

Fifty yards west of this cave there is another one which is about 50 feet long, 30 feet wide, and 10 feet high near the entrance. It is situated about 30 feet above sea level, and its mouth is almost closed up with grass-grown cliff-talus. The upper end of the cavern is full of large and small water-worn boulders. The fishermen told me that the cave mouth had been choked with fallen rock as I saw it, during all the twenty-five years of their residence at the Cape.

A third cave, known as the water cave, lies immediately north of the big cave. Its floor is still so deep under water

that in fine weather the rollers do not break when they enter it. I judge that the depth of water must be 20 feet.

A fourth cave, near by, is three or four feet above high water mark, and it is so dry that the fishermen have lived in it for months at a time.

The positions of these caverns relative to the sea level, point to a still proceeding elevatory movement of the coast.

The big cave must have been quite 20 feet lower when the ocean carved it out. The second of those described is now far out of reach of the waves. It must have stood 50 feet lower than it does to day, when the grind of the surf bored it out of the rock, and ages may have passed since its rolled stones were last wet with the surf.

The fisherman's cave must have altered its level by 24 feet, but the great water cave is still in the course of erosion having its floor about 20 feet beneath the sea surface, and its roof 15 feet above it. Every lift of the sea must roll the grinding shingle upon its floor, and, in rough weather, the air suction due to the draw-back, must be an enormous force, quite sufficient to drag out of its walls every block of stone that the battering of the breakers has loosened.

While the existence of these raised beaches is evidence of an upward movement, the occurrence of exceedingly deep water at the very foot of some of the cliffs is an indication that the present elevatory movement was immediately preceded by a considerable depression. If we take the Admiralty chart and note the soundings we shall see that the cliffs on the east side of Cape Grant have their bases in 72 feet of water. They rise almost sheer from that great depth. The soundings and the outlying rocks show that the present line of cliffs does not represent the original southern edge of the lava flow. That margin lay out in the offing. Its present position is due to the fact that the cliff has been cut back by the sea. The rocky floor, now 70 feet deep under water, must once have been at least 50 feet higher, to allow the waves to operate upon the mass out of which its precipices have been carved. Since that time there has been a downward movement, and an upward one, the latter of which has long been in progress, and has, moreover, been varied by several periods of rest.

Conclusion.

It may be noticed, that my sketch map differs materially from the Geological map issued by the Government. I might

say, that before I commenced the task of preparing mine, to avoid going over ground already occupied, I took the precaution of asking at the office of the Geological Survey Department what data it possessed in relation to the Portland promontory. In reply to this enquiry I was told that the Government Geological Surveyors had not visited it, and that the department had no official records of its character, nor any plans of the district. My map does not pretend to be more than a first sketch. Before it can be complete many details will have to be filled in, and some parts of the boundaries of the formations on the north-western base of the promontory may be modified, as the result of a fuller examination. In the mean time, if it should point out an interesting field of work to other geologists, it will have served its purpose.

Art. VII—*On the value of* J, *and the value of* g.

By Professor H. M. Andrew, M.A.

[See Proceedings, page 91.]

Art. VIII—*Note on the Proposed Photographic Charting of the Heavens.*

By R. L. J. Ellery, F.R.S., F.R.A.S.

[See Proceedings, page 93.]